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BLACK-LEG DISEASE OF BRUSSELS SPROUTS, CABBAGE, AND CAULIFLOWER

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Bulletin No. 550

BLACK-LEG DISEASE OF BRUSSELS SPROUTS, CABBAGE, AND CAULIFLOWER

E. E. CLAYTON

ABSTRACT

Black-leg is a disease which has been known on Long Island for more than 20 years. Recently, it has become very destructive.

This report covers experiments conducted between 1922 and 1927, with the object of developing practical and effective control measures for this disease. At the time the work was begun the growers practiced no control measures and attributed their losses from disease to poor seed, maggots, and a variety of other causes.

The sources of the black-leg infection may be in the seed or in the soil. Locally-grown seed of brussels sprouts and cabbage is very commonly infected with black-leg and the causal fungus lives practically as long as the seed. The fungus will also live in soil for three years.

The disease produces spots on leaves, stems, and pods, but does its damage by rotting the tap root and stem from the surface of the ground down. The decay of the stem and root progresses very slowly and the diseased plants often linger on for the entire summer.

Infection takes place during the latter part of the plant bed period, tho injury is not usually apparent before the crop is half grown.

Tests of large numbers of cabbage and cauliflower varieties and strains have shown that all are susceptible to the disease. Similar trials with brussels sprouts, however, have discovered one strain that was partly resistant.

Seed treatment trials proved that hot water treatments are effective. Numerous chemical soaking and dusting treatments have failed to give as good results.

The following control measures have been tried out on a large scale with very satisfactory results.

1. Rotation of seedbed and field areas, selecting land for the seedbed that has grown none of the susceptible crops for the previous five or six years, and land for the field that has grown other crops the previous three years.

2. Seed treatment, soaking all cabbage and brussels sprouts seed in water at 122° F (50° C) for 25 minutes. All cauliflower seed should be soaked 18 minutes, not to destroy black-leg because it is not carried on cauliflower seed, but to destroy black-rot which may be present on the seed.

The combined seed treatment-rotation program has enabled growers who formerly suffered heavy losses from black-leg to control the disease completely. Such results cannot be attained, however, except by using the most effective form of seed treatment and by taking the greatest care in selecting a location for the seedbed.

ECONOMIC IMPORTANCE OF BLACK-LEG

Black-leg is a very destructive disease that has been the cause of heavy crop losses on Long Island, particularly during the last decade. The fact that whenever it appears in a field it may destroy up to 90 per cent of the plants makes this disease especially feared by the growers. Of the cruciferous crops largely grown on the Island—cabbage, cauliflower, and brussels sprouts—the last named has suffered especially from black-leg.

Previous to the investigations here reported, growers of brussels sprouts had given little attention to control measures, with the result that in 1922 it was conservatively estimated that 15 to 20 per cent of the entire crop was destroyed by black-leg and losses of individuals ran into thousands of dollars. Cabbage and cauliflower were also attacked by the disease, but, owing to circumstances to be brought out later, the losses with these crops, while serious, have not been so outstanding.

Black-leg is certainly a disease that every grower of cruciferous crops should guard against most carefully; for once introduced on a farm it not only causes serious immediate damage but it may also recur in later years and become a continuous source of trouble.

HISTORY OF THE DISEASE

Black-leg was reported by Stewart (7)[1] to have occurred on Long Island in 1903. It was probably observed in Minnesota in 1906 by Washburn (10) and was first definitely described by Manns (3) in Ohio. The probability is that the disease has been present in this country for a long time, since its ability to spread with seed

[1]Refers to Literature Cited, page 26.

makes its introduction into new localities very easy. The disease is often confused with maggot injury because the stems of infected plants are frequently invaded by the maggots of flies which feed on dead and decaying vegetable matter, and for this reason much damage done by black-leg is assigned to maggots.

The disease has been reported by Bos (1) as seriously affecting cabbage in several parts of Europe.

In Holland this disease was reported no longer serious by Walker (8). Van Keulen (6), however, states that the disease causes very severe damage in northern Holland. Black-leg was reported in 1901 by McAlpine (4) as being a very serious disease of cauliflower in Australia. That black-leg is still an important problem in Australia is indicated by Birmingham (2) who states that the disease was extremely destructive with cabbage and cauliflower in the provinces of New South Wales in 1924.

APPEARANCE OF THE DISEASE

Black-leg attacks the plant stem, causing its decay from the surface of the ground down. The decay is a dry rot that leaves a dead brown stub below ground. As the stem and roots are destroyed, the diseased plants die, tho many are kept alive by a few roots thrown out at the surface of the ground above the decay. Such plants often blow over or topple over at a touch of the foot. The decayed stem and root are invaded by worms, and hence growers, as has been mentioned, frequently mistake black-leg for the work of the cabbage maggot. There is little occasion for the confusion, however, since on Long Island maggots are active in the fields during the early summer only, while it is the main crop grown during late summer and fall that suffers from black-leg.

CAUSE OF THE DISEASE

Black-leg is a disease caused by the fungus *Phoma lingam* (Tode) Desmaz. This fungus is easily isolated by the usual cultural methods and pure cultures are readily obtainable by the spore dilution method.

SEASONAL DEVELOPMENT

The fungus attacks the seed pods (Plate I) and penetrates thru and into the seed in which it readily survives for two or three years. Apparently, the fungus remains viable as long as the seed. A soil which has grown a diseased crop retains the infection for two years and, in slight degrees, for three or four years.

When infection is seed-borne, the fungus is sown with the seed and hence is in position to attack the developing seedling immediately. This it kills in a short time and the fungus may spread and attack other closely adjacent seedlings growing from healthy seed. The fruiting bodies of the fungus are produced freely on the dead or dying seedlings and spores are matured within a month of the date of seed sowing. The maturing of these spores prior to the time the plants are transplanted makes possible an intensive spread of this disease during the latter part of the seedbed period.

Quanjer (5) laid much emphasis on the relationship between maggot injury and black-leg infection. On the other hand, Manns (3) in Ohio observed no connection between maggot injury and black-leg infection. On Long Island the main cruciferous crops are grown in the fall and seldom suffer from maggot attack. Black-leg infection occurs freely nevertheless, indicating that this fungus is able to enter the plant without the aid of maggots.

Observations over a period of years have shown that the chief points of primary infection are the cotyledons and, more rarely, the first or second leaf (Plate II). The pycnospores reach these parts by rain spattering which carries them either from the dead seedlings, on which the fruiting bodies previously referred to are located, or, in case of soil infection, it is probable that spores are spattered directly from the soil. The cotyledons are very readily infected and the fungus grows down the petiole and into the main stem of the plant, entering this at the point of origin of the cotyledon. Thus, in a diseased seedbed close observation will show numerous plants with the dead and withered cotyledons still attached, and sometimes these will be covered with the pycnidia of the black-leg fungus. When leaves other than the cotyledons are infected, the fungus has farther to travel before it gains the main stem.

Observations have shown that when infection of the first or second leaf occurs on the petiole the fungus usually grows down and into the stem despite the distance it must travel. Where the infection occurs on the leaf-blade, however, it remains local and does not reach the main stem. The stem itself is occasionally infected directly, but in all such cases the entrance of the fungus is made possible by a growth crack or other injury. Roots also are only infected directly thru injuries. Thus, black-leg infections of the tap-root which centered about maggot injuries have been observed several times. These are not very frequent, since, as has previously been mentioned,

maggot injuries are uncommon with the late season crops where black-leg is a problem. Direct infection either of stem or root consequently has been a comparatively rare occurrence under Long Island conditions.

After the fungus has traveled thru the cotyledon and reached the main stem of the plant it ceases to make rapid progress. Occasionally plants at the time of setting-out, which is from four to eight weeks after seed sowing, show good-sized black-leg cankers. The vast majority of infected plants, however, show at this time only a very inconspicuous bluish lesion centering about the cotyledon scar. During the course of these experiments many lots of plants have been grown from diseased seed which at the time of transplanting showed no lesions that could be identified as black-leg, the disease not having progressed far enough. To the observer, these plants appeared healthy. Later, the disease developed in the field, however, and from 75 to 90 per cent of the plants were killed before the end of the season.

DISTANCE OF DISEASE SPREAD IN THE PLANT BED

During the course of this work, plantings of healthy and diseased seed have been separated from one another by various intervals to discover how far the infection may be carried. It has been found that this disease spreads intensively for a distance of only 2 or 3 feet and that healthy plantings separated by a 6-foot interval from diseased plants will later show little or no infection. While this holds true generally, it is important to note that occasionally the disease has been able to cross an interval of 12 feet and cause considerable damage. During the course of field inspections of plant beds for various growers, however, the writer has several times discovered a diseased seedbed sown with seed from several sources. In all such cases the plants from one lot of seed showed black-leg infection, while the plants from the other lots appeared healthy. These growers were able in each instance to secure a healthy crop by discarding all plants on the area sown with infected seed and in addition the plants on an adjacent strip 5 or 6 feet wide sown with healthy seed. It is to be noted, that these measures, while effective with black-leg, could not be used with black-rot since the latter disease is able to spread freely for much greater distances.

PROGRESS OF THE DISEASE IN THE FIELD

When plants are transplanted into the field they are set several inches deeper in the ground than they stood in the plant bed. Consequently, the stem infections at the level of the cotyledons, which

were an inch above the ground in the bed, are 1 to 2 inches below ground in the field. In this way what began as an aerial lesion affecting the stem becomes a decay affecting the tap-root (Plates IV and V). The change from air to soil appears very agreeable to the fungus which now confines its activity to the root and stem, progressing upward only as far as the soil surface. When plants infected in the bed are set out in the field they may die within a week of transplanting, or the disease may develop slowly and new roots may be thrown out above the decayed zone enabling such individuals to survive part or all of the season. In this way there is a constant dropping out of plants over a long period with the result that a grower who begins to replant with the expectation of losing 5 or 10 per cent of his stand finds to his surprise as the summer wears on that his loss will be 50 to 75 per cent.

So far as it has been possible to determine, practically every plant that developed black-leg to a serious degree in the field contracted the infection while in the seedbed. This was true whether the disease killed the plant one week or two months after transplanting. The rarity with which the disease spread after the plants were moved from seedbed to field was very striking. Thus, in repeated experiments plats of healthy plants have been located in the midst of diseased plants and the healthy plants have always made a normal growth, apparently entirely unaffected by the dead and dying individuals in the adjacent rows (Plate III). This inability to spread in the field may be due to one or both of two reasons.

First, as noted in the discussion of the seedbed spread, the spores are scattered in large numbers for only very short distances. In the bed where the plants are close together this is no handicap to the fungus, but in the field with the plants 2 and 3 feet apart it is an important factor in its spread.

Second, the fungus is able to enter the plants in the seedbed with ease because of the susceptibility of the cotyledons. In the field this avenue of entrance is closed and the plants are better able to resist infection, as well as to delay disease development, after infection has occurred. The importance of this factor is indicated by the fact that, altho healthy plants growing in the midst of diseased ones make a normal growth, many are nevertheless infected and if brought into the greenhouse in the fall and grown there in pots during the winter this infection becomes evident and ultimately destroys them.

FACTORS WHICH AFFECT THE SEVERITY OF DISEASE DEVELOPMENT

Black-leg is a disease that seems never to be equally severe in any two plantings. These differences are puzzling to the grower who may make what he feels are two similar plantings from the same bed and suffer more than 50 per cent loss in the one and less than 10 per cent in the other. Sometimes the explanation is that the plantings are from two different lots of seed, only one of which was infected. Such variations occur, however, in fields set from the same plant bed with plants grown from the same seed. Also, a half dozen growers using the same lot of diseased seed may suffer losses which vary widely; so, in view of the fact that such variations occur on the same farm or with growers located close together, it is impossible to attribute them to climatic changes. Much of the variation, however, may be accounted for in the following ways.

First, the grower who makes a series of plantings from the same diseased seedbed usually discovers that the fields or portions of fields set early show less disease than those set late. The difference in time between the first and last setting from a single seed sowing may range from two weeks to a month and the longer the plants stand in the plant bed the greater the opportunity for the infection to spread.

Second, soil differences appear to have a marked effect on the resistance of the plants to the disease. Lots of healthy and diseased plants from the same seedbed were set out in four locations in 1925. The healthy plants remained free from infection in all four places, while the diseased plants suffered losses varying from 15 to 90 per cent. The lowest loss, 15 per cent, occurred with the planting at Riverhead and the soil here was quite heavy. The highest loss, 90 per cent, resulted in Farmingdale plats where the soil used was light.

Investigations showed that at Riverhead many plants were infected, but the infection in most cases made little progress and the plants developed normally; while at Farmingdale, so far as could be determined, every infected plant was killed. All of these plants were from the same seedbed and they were set out on the same day. In other instances variations almost as striking as this have been observed in different fields on the same farm. Just what the soil conditions are that favor or retard disease development, however, is by no means certain, tho in general the plants on lighter land are killed most quickly.

SEED AND SOIL AS SOURCES OF BLACK-LEG INFECTION

It is interesting and often of great importance to determine the source of infection. During the past five years, the writer has had occasion to determine the source of infection for a great many outbreaks of black-leg. It is possible for the infection to come (a) from the seed, (b) from the seedbed soil, or (c) from the field soil.

The distinction between seed and soil infection is of practical importance, since in the one case responsibility is shared by the seedsman who sold the seed to the grower, while in the other the grower has only himself to blame. Whether infection is from seedbed soil or field soil also makes a great difference.

In deciding the source of infection the first consideration is the severity of the attack. Soil infection encountered only in the field after the plants are set out rarely causes severe loss. Generally, the disease appears late in such cases and a few scattering plants are affected. Often the loss of plants is 1 or 2 per cent, and rarely is it over 15 per cent. Consequently, in all instances where the attack is severe it is almost certain that the disease was encountered in the seedbed and hence came either from the seed or the seedbed soil. If all the plants in the seedbed were grown from a single lot of seed, the only way to distinguish infection from seed and infection from seedbed soil is to look up the history of the particular seed lot, discover who else planted it, and visit them. Most beds on Long Island contain plants from more than one lot of seed, however. This makes it possible to determine at once whether the infection originated with the seed or the seedbed soil.

Sprouts, cauliflower, and cabbage are all very susceptible to the black-leg disease and, consequently, if the disease affects equally all lots of plants of these sorts which come from a single plant bed, it is practically certain that there is a common source of infection, namely, the soil in which the seeds were sown. If, on the other hand, the disease is very severe in one lot of plants while others grown in the same bed show only a few scattering sick plants, this points to the one seed strain as infected, while the scattering diseased plants in the other lots of plants are the result of spread from the diseased sowing to the healthy. The fact that the disease spreads only very short distances in the plant bed makes this distinction possible.

In summary, then, a severe attack of black-leg indicates early infection and spread of the disease in the plant bed; hence the source of infection is either the seed or the seedbed soil. A light attack

developing late in the season is usually the result of infection encountered in the field after transplanting. Seed-borne infection and infection carried by seedbed soil can be separated by the fact that the seed-borne infection will largely be confined to the plants grown from a particular lot of seed, while the soil-borne infection will attack with about equal severity all lots of cabbage, cauliflower, or sprouts that were sown in the infected bed.

CONTROL OF BLACK-LEG

Black-leg is now being effectively controlled by most Long Island growers and the measures used—seed treatment and seedbed rotation—are as effective as they are simple and inexpensive.

It is first essential that seedbed soil infection be avoided, for the presence of a trace of disease here is likely to cause a destructive disease outbreak, while a similar slight amount of disease in the field soil would cause little or no loss. Seedbeds on Long Island are quite large and often located a long distance from water. Consequently, seedbed disinfection is not a practical possibility, the more so since the same end can be gained by careful rotation.

Seedbeds should be located on ground that has not grown green crops (cabbage, cauliflower, and brussels sprouts) for the previous five or six years. Seedbeds, also, should not be located on land that may have received refuse from one of these crops. Thus, occasionally severe epidemics of black-leg are traced to plant beds located near a sprout picking house, and in these cases the old leaves had been carried out and dumped on this ground.

Every grower has heard of the man who grew his plants in the same bed for five or ten years and never was bothered by disease. Theoretically, it is perfectly safe to locate the seedbed in the same spot year after year so long as no disease appears, or to locate the bed on ground that grew a crop of cabbage or sprouts a couple of years previous, providing that crop was perfectly healthy. Actually, however, where one man succeeds in doing these things another fails, and the chances of success are certainly not worth the gamble. In fact, few feel that they can afford to take unnecessary chances, so the only safe procedure is to rotate the seedbed area very carefully.

The rotation for the field need not be so exacting as the rotation for the seedbed, but it requires a certain amount of attention. Many observations have shown that where growers follow a black-leg diseased crop by another cruciferous crop the next year, the loss

from the disease may be from 50 to 75 per cent, indicating that a large amount of infection lives over one winter. Where growers have waited one or two years, however, the losses have been much less severe. The maximum loss observed under these conditions has been 20 per cent, the minimum none at all, and the average from 5 to 10 per cent. Plantings made the fourth year or more following the black-leg outbreak have in most cases shown no disease.

On the basis of these observations it is believed that the best rotation for black-leg control is one year of green crops followed by three or more years of other crops. In place of this four-year rotation many growers use a three-year system very successfully, providing they do not have too much disease to cope with. Obviously, anyone who wishes to use a short rotation must first reduce the incidence of disease to a minimun if they wish also to avoid severe losses. The standard recommendation, however, is six years or more rotation for the plant bed and four years for the field.

Seedbed and field rotation are intended to deal with soil-borne black-leg infection. Infection is often carried in the seed, and consequently seed treatment to destroy all seed-borne black-leg is of prime importance. Various treatments have been recommended of which the chief methods are soaking in mercuric chloride, 1 to 1,000, for 20 to 30 minutes, and the hot water treatment, using water at 122° F (50° C) for 30 minutes. These treatments and many others have been tried out in the series of tests conducted over the past five years. The details of this work are too extensive to be discussed here, but suffice it to say that hot water is the most effective method of seed treatment for black-leg. The various forms of chemical soaking and dusting are distinctly inferior and should only be used as a second best alternative.

Hot water treatments that are equally effective have been worked out for temperatures ranging from 122° to 140° F. Since equally good disease control can be secured at 122° as at higher temperatures and since danger of seed injury is less than at higher temperatures, soaking in water at 122° F for 25 minutes is recommended. There is no gain in disease control from longer soaking, nor can the treatment be shortened without losing effectiveness.

Detailed accounts of the numerous seed treatment experiments will be published elsewhere, but two of the experiments will be reported here to illustrate the sort of data from which the conclusions have been drawn and also the relative effectiveness of some different forms of seed treatment.

COMPARISON OF HOT WATER AND CHEMICAL SEED TREATMENTS FOR BLACK-LEG

This experiment was conducted in 1925 at Farmingdale on the grounds of the State Institute of Applied Agriculture with the cooperation of Prof. S. Gray. The following treatments were compared.

1. The standard hot water treatment, consisting of 25 minutes soaking in water at 50° C.

2. The standard mercuric chloride treatment, soaking for 30 minutes in a 1 to 1,000 solution.

3. An organic mercury treatment, using Metaphen, 1 to 1,000. and soaking for 2 hours.

4. An organic mercury dust, Semesan.

The seed treated was a lot of severely diseased red cabbage. All lots germinated well and up to the time of transplanting all grew well with no differences apparent between lots. After transplanting, however, it developed that some lots required more resetting than others. A record was kept of the total number of plants set into each plat. In the fall, also, counts were made of the number of plants headed, the weight of the heads cut, and the number of heads cut in each plat. These records are given in Table 1. (See Plate VII.)

Table 1.—Effect of Seed Treatments for Black-leg on Number of Plants Heading.

Treatment	Number of plants set on June 29	Number of replants on		Total number set	Plants headed Nov. 10		Percentage increase in number plants headed due to treatment
		July 15	July 25		Number	Percentage	
Untreated checks—7 plats	210	69	66	345	50	14.5	0
Hot water, 25 minutes at 50°C—7 plats	210	16	13	239	191	79.9	451.4
Mercuric chloride, 0.1 per cent for 30 minutes—7 plats	210	106	103	419	80	19.1	31.7
Semesan dust—7 plats	210	46	43	299	75	25.1	73.1
Metaphen, 0.1 per cent for 2 hours—7 plats	210	41	43	294	108	36.4	151.1

TABLE 2.—EFFECT OF SEED TREATMENTS FOR BLACK-LEG ON WEIGHT OF CABBAGE CUT.

TREATMENT	WEIGHT OF CABBAGE CUT OCT. 9, POUNDS	NUMBER OF HEADS CUT OCT. 9	PERCENTAGE INCREASE IN WEIGHT OF CABBAGE, TREATED LOTS COMPARED WITH CHECK
Untreated checks			
Plats: 1	26.6	11	
2	2.8	2	
3	22.0	7	
4	20.0	9	
5	3.2	2	
6	3.0	2	
7	4.2	1	
Totals	81.8	34	0
Hot water, 25 minutes at 50°C			
Plats: 1	60.0	23	
2	48.0	18	
3	67.5	26	
4	34.8	15	
5	38.7	16	
6	53.5	20	
7	58.0	23	
Totals	360.5	141	340.7
Mercuric chloride, 0.1 per cent for 30 minutes			
Plats: 1	11.7	6	
2	28.3	10	
3	20.0	8	
4	26.0	10	
5	3.7	3	
6	18.5	7	
7	15.5	6	
Totals	123.7	50	51.2
Semesan Jr. Dust			
Plats: 1	3.0	2	
2	19.7	8	
3	31.5	7	
4	15.8	8	
5	28.8	11	
6	24.1	9	
7	39.5	13	
Totals	142.4	58	74.1
Metaphen, 0.1 per cent for 2 hours			
Plats: 1	30.2	14	
2	13.0	7	
3	8.0	4	
4	24.0	10	
5	37.0	13	
6	48.3	21	
7	22.5	10	
Totals	183.0	79	123.7

PLATE I.—BLACK-LEG LESIONS ON CABBAGE SEED PODS.

The upper pod shows a spot with the fully developed, black, dot-like fruiting bodies (pycnidia) of the fungus. Below is an earlier stage. The presence of the fruiting bodies is necessary for the identification of a spot as black-leg. Without these the lesions cannot be distinguished from the pod spots caused by other relatively harmless organisms.

PLATE II.—BLACK-LEG LESIONS ON STEMS OF PLANTS GROWING IN THE SEEDBED.

A and B are lesions that entered the stem by way of the cotyledons, the usual point at which plants are infected since the fungus does not appear able to penetrate the uninjured stem directly. C is a stem lesion that resulted from infection of the petiole of the first leaf.

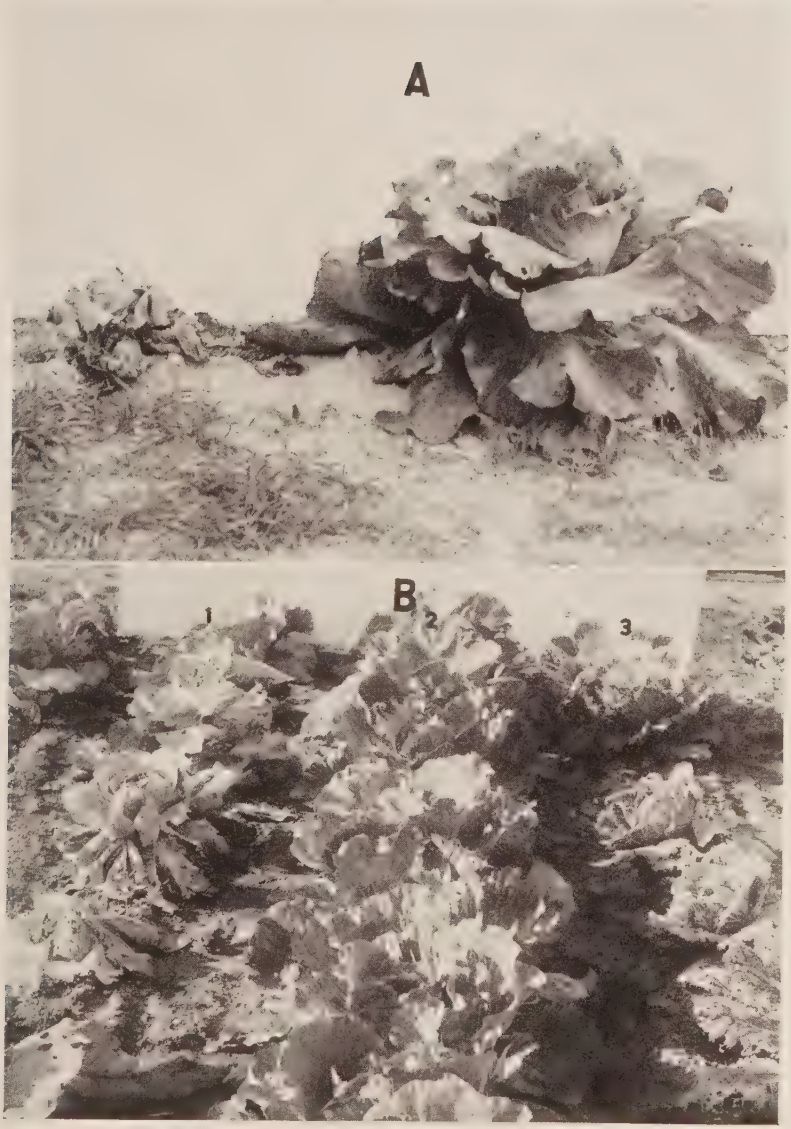

PLATE III.—BLACK-LEG IN CABBAGE.

A, black-leg diseased (left) and healthy (right) cabbage plants.

B, Row 2 was set with plants from a healthy seedbed, rows 1 and 3 with plants from a diseased seedbed. Note that row 2 plants are making a healthy growth, while every plant in rows 1 and 3 is either dead or dying. The disease spreads rapidly in the plant bed, but in the field, as this shows, a row of healthy plants makes a healthy growth even tho set in the midst of diseased rows.

PLATE IV.—HEALTHY (A) AND BLACK-LEG (B) BRUSSELS SPROUTS ROOTS.

Note that with the diseased plant all that remains of the original root system is a dry, decayed stub above which new roots have been thrown out. These new roots were sufficient to permit this plant to make a stunted growth.

PLATE V.—HEALTHY (A) AND BLACK-LEG (B) CAULIFLOWER ROOTS.

Note that, unlike the diseased sprouts plant, the diseased cauliflower plant has thrown out few new roots. This difference is characteristic and the consequence is that a larger proportion of affected cauliflower plants are killed outright by the disease.

PLATE VI.—RESISTANCE TO BLACK-LEG.

Row 1 was set with susceptible strains and row 2 with strains selected for resistance.

PLATE VII.—SEED TREATMENT FOR BLACK-LEG.

B, Seed soaked in organic mercury; increase in yield over check 123 per cent.
E, Untreated check.
C, Hot water treated seed; increase in yield 340 per cent.
D, Mercuric chloride treated seed; increase in yield 51 per cent.
A, Seed dusted with organic mercury; increase in yield 74 per cent.

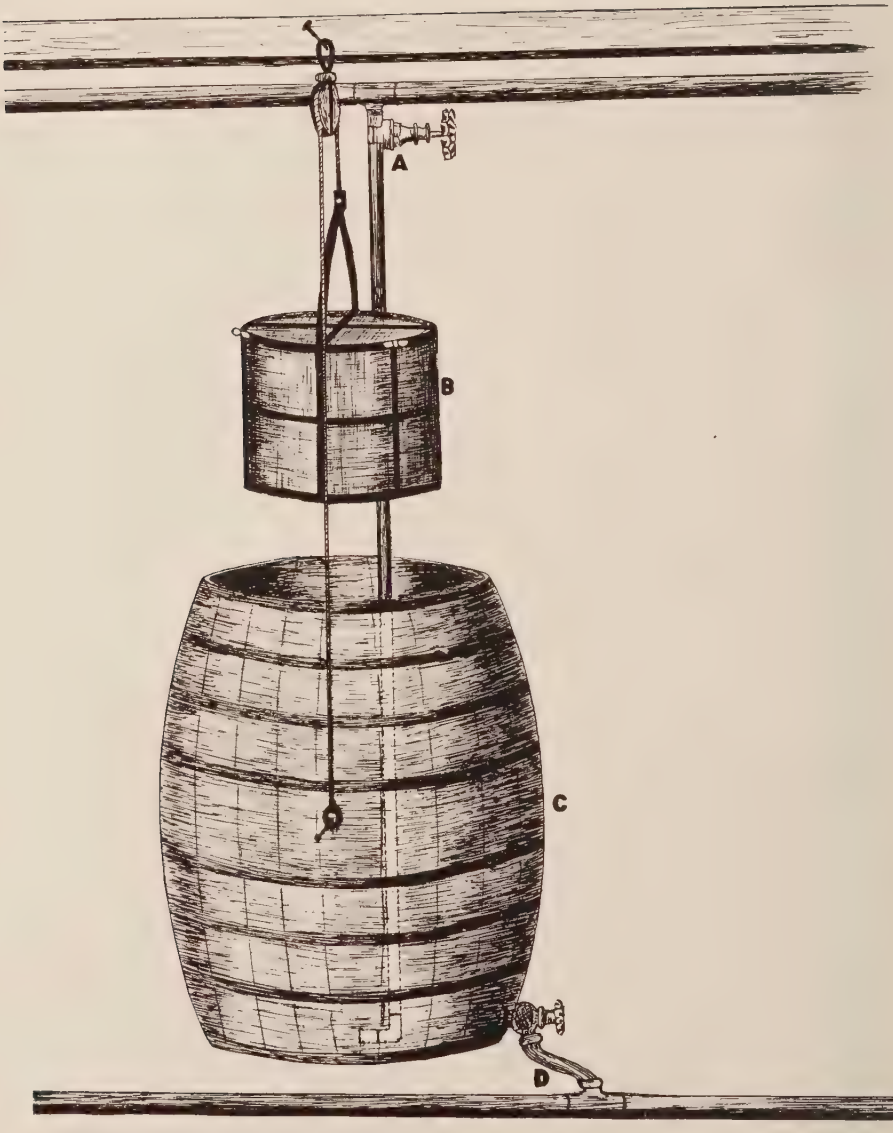

PLATE VIII.—SEED TREATMENT APPARATUS.

The seed treating plant used in this work was equipped with two hot water barrels and seed baskets like the ones here shown. The baskets were made of strap iron and 30 mesh to the inch brass wire cloth. Steam was let in at the bottom of the barrel by the down pipe that passed just inside the back. Barrels were drained, washed, and filled with clean water each day before using. A, Steam pipe. B, Seed basket. C, Hot water barrel. D, Drainage outlet.

The development of the disease was virulent and conditions favored a critical test of the effectiveness of the treatments. Under these conditions the hot water treatment, judged either by the percentage of plants heading or by the weight of heads cut, gave outstandingly the best results. Metaphen gave distinctly better results than did mercuric chloride or Semesan Jr., but all three failed to give satisfactory control of the disease.

COMPARISON OF HOT WATER TREATED AND UNTREATED COMMERCIAL BRUSSELS SPROUTS SEED

An experiment such as the previous one measures the difference in effectiveness between different forms of seed treatment very well. The question remains: Does it pay to treat the ordinary commercial seed? Obviously many lots of seed are free from disease and hence do not need treatment, while other lots carry infection of one or more kinds. There is no way of telling, however, whether a seed stock is infected or healthy, and hence the only safe procedure is to treat all seed. In 1925, and again in 1926, samples of the seed that the growers brought in for treatment were taken before and after the seed was processed. Each year a series of treated lots of sprouts seed and another series of untreated lots from the same seed were planted. The 1926 series consisted of 26 separate lots of seed. The writer was fortunate in having this year the cooperation of three very careful growers who gave their personal attention to the details of the test. Each planted in two seedbeds, separated from one another, 10 lots of sprouts seed, in one bed untreated seed and in the other bed hot water treated seed. The seed was sown the first of June, 1926, and the plants set out about July 20. Enough plants were set from each seedbed strain to make a row across the experimental field, and consequently the field plantings consisted of 10 rows from as many strains with treated seed and 10 rows of the same strains with untreated seed. The rows were labeled by number only and no information as to the identity of the different plats was furnished until fall.

Late in October the different plantings were scored by a committee of competent growers. The basis of the scoring was as follows: 30 points for vigor and uniformity of plants; 35 points for quality of yield; 35 points for quantity of yield.

The results are given in Table 3.

TABLE 3.—COMPARISON OF TREATED AND UNTREATED SPROUTS SEED IN 1926.

LOCATION OF PLATS	SEED STRAIN USED	TOTAL POINTS SCORED BY	
		Hot water treated seed	Untreated seed
Hallock Farm, Orient, L. I.	Geo. Howard	59	22
	Wm. Haberman	64	34
	Wm. Karcher	66	19
	Geo. Hallock	75	17
	Peter Brown	52	20
	Peter Hand No. 1	60	31
	Peter Hand No. 2	49	40
	Joe Zimnowski	57	43
	J. F. Douglass	80	48
	H. S. Duvall	68	40
Sterling Farm, Cutchogue, L. I.	H. M. Reeve	63	65
	Joe Zimnowski	52	57
	H. S. Duvall	86	38
	Geo. Hallock	63	38
	Wm. Haberman	68	73
	Peter Hand	60	39
	E. Wiggins	60	61
	R. Sterling	73	75
	Frank Young	50	47
	T. Gadomski	74	68
Kirkup Farm, Mattituck, L. I.	Peter Nartowicz	47	16
	John Moisa	63	16
	John Sledjieski	56	16
	Jake Popleski	59	18
	John Trycowski	45	21
	Geo. Howard No. 1	45	16
	Geo. Howard No. 2	43	19
	Peter Hand	65	18
	H. S. Duvall	55	25
	Philip Burke	71	32
Totals	Thirty tests	1,828	1,072
Averages	Thirty tests	61	36

The most severe development of black-leg was in the Kirkup test and more occurred in the plants from treated seed than usual. There was much black-leg in the untreated seed plats at the Hallock Farm, but very little in the treated seed plats there. At the Sterling Farm black-leg was serious in only a few plats, all of which were planted with untreated seed. It is to be noted that with several of the strains in this test the untreated out-scored the treated by from 1 to 5 points, and similarly the reverse. These slight differences have no significance. It is interesting to note that in the test at the Sterling Farm the H. S. Duvall strain hot water treated scored

highest with 86 points and untreated scored lowest with 38 points. The difference was due to the fact that this strain as such was well selected, but it was heavily black-leg infected. With seed untreated the disease was the limiting factor, whereas with treatment this depressing influence was removed and the true value of the strain was revealed. In general, the test emphasized what has been commonly recognized, namely, that there is plenty of disease in the locally grown sprouts seed and seed treatment is very necessary. It is understood, of course, that in such a test as this two or three infected strains of seed probably were sufficient to contaminate a seedbed and, consequently, that some healthy strains suffered because they were sown in the seedbed adjacent to diseased ones.

PRODUCTION OF SEED FREE FROM BLACK-LEG INFECTION

Seed treatment is admittedly some bother and also it involves a certain amount of risk. To avoid this Walker (9) has suggested that seed be grown in the Puget Sound region where climatic conditions are such that the disease does not develop in seed fields even when the stock seed from which the crop is grown is known to be infected. In this connection the writer has proved experimentally that rainfall during the early stages of seed pod development is essential for the occurrence of seed infection. Long Island growers of cabbage and brussels sprouts for market, however, depend entirely on home-grown seed and they give much care to carefully selecting and maintaining their strains. They will not consider entrusting this to others and consequently the writer devoted attention to the possibility of producing disease-free seed on Long Island.

It was found possible to treat seed stocks and grow plants apparently 100 per cent healthy. Healthy plants were also produced from stock seed grown in the greenhouse. Mother plants selected from such lots were then set out on land that had grown no cruciferous crops for at least three years previous. Inspection of these plantings during the growing season showed that by exercising care it is possible to reduce greatly the chances of seed infection, but with even the best of attention disease several times developed in small amounts. The author has cooperated in similar work with a number of local seed growers with like results. Local growers consequently have come to recognize the need of exercising the utmost care in seed production but do not depend on the seed being free from disease.

Since some seed lots are diseased and others healthy, the next problem considered was whether it would be possible by inspecting the growing crop to certify certain lots of seed as disease free. The outstanding success of seed potato certification lends a strong appeal to this idea. In the beginning, however, it appeared doubtful whether inspection could be intensive enough to be effective. A very small amount of pod infection may cause severe losses in the crop grown from that seed, and it does not appear that inspection could be thoro enough to discover and destroy all of the disease. However, the matter was tried out during 1924, 1925, and 1926. It was known that prior to pycnidia formation the black-leg lesions could not be separated from the spots caused by other relatively harmless parasites and consequently all inspection work was of necessity confined to the last two or three weeks before harvest. The record of the 1926 inspections of sprouts seed plantings given in Table 4 is of interest. The inspections were made from July 13 to 20, 1926.

Table 4.—Occurrence of Black-leg in 1926 Sprouts Seed Crop.

Seed grower	Black-leg infection
Ralph Sterling	No
Wm. Haberman	Yes, slight
H. S. Duvall	Yes, slight
Paul Edwards	No
B. D. Latham	Yes
J. F. Douglass	Yes
J. C. Cooper	Yes
Peter Hand at A. B. Gordon's	No
at Wm. Terry's	No
at Wm. Terry's	Yes
George Hallock's	No

The first inspection of most of these plantings was followed in most cases by a second inspection a week later. All plants bearing infected pods were cut out and removed at the time of the first inspection, nevertheless one planting found clean at the first inspection showed pod infection at the second, and several plantings from which the pod infection had been cut out showed newly develped pod lesions. The seed was cut before there was time for another inspection, but had there been time it seems reasonable to suppose that there would have been additional pod lesions developed. The continuous development of pod lesions, of which only those bearing

pycnidia can be distinguished, makes it impossible to rogue out a seed planting effectively and impossible to say that a planting is free from black-leg infection. This was the experience in 1926 and also in previous years. Consequently, the chief value of inspection work under Long Island conditions is the information it gives of the prevalence of disease in the current crop of seed. Thus, the 1926 record indicated general pod infection and great need for seed treatment. In addition, the removal of plants bearing infected pods certainly reduces the amount of seed infection.

RESISTANCE TO BLACK-LEG

Various observers have pointed out differences in susceptibility to this disease among cabbage, cauliflower, and brussels sprouts, but there is not complete agreement in these observations. On Long Island the brussels sprouts crop suffers most severely from black-leg, while cabbage and cauliflower suffer to a lesser degree. However, whenever the disease attacks these latter two it is very destructive and the plants succumb with equal or greater rapidity than sprouts. Furthermore, comparative inoculations in the greenhouse have indicated that all were about equally susceptible. The difference in the losses appears to be explained by the fact that the brussels sprouts seed, which is locally grown, very commonly carries black-leg infection, while the cabbage seed is only occasionally infected, and the cauliflower seed, all of which is imported from Holland and Denmark, is apparently free from all black-leg infection. This latter observation is in agreement with Walker's (8) report that he observed none of this disease in his inspection of these seed-growing areas.

Aside from the difference in susceptibility of the three distinct crops, some workers have reported differences in susceptibility among varieties of cabbage toward black-leg, and the possibility has been given some attention. In 1926, seed of the following varieties was sown in a special plant bed and the young plants were heavily inoculated by spraying with a suspension of spores.

White Cabbage: Copenhagen Market, Jersey Wakefield, Charleston Wakefield, Glory of Enhuizen, Allhead Early, Early Summer, Eureka, Steins' Flat Dutch, Premium Flat Dutch, Surehead, Louisville Drumhead, Houser, Wisconsin Hollander, and Danish Baldhead.

Savoy Cabbage: Earliest Round, Earliest Savoy, Two Monthly, Dwarf Ulm, Iron Head, Drum Head Savoy, and Late Flat Savoy.

Red Cabbage: Haco, Simonson, Danish Stonehead, Mammoth Red Rock, Blood Red Late Dutch, Dark Red, and Blood Red Berlin.

Infection was general in the plant bed and no differences in varietal susceptibility could be distinguished, so 15 of the best plants of each variety were set out in field plats. Out of the entire planting there were only a couple of plants that did not develop the disease before the end of the season; and while some varieties died more quickly than others, the evidence was that no variety possessed appreciable resistance.

In addition to the cabbage, the writer has inoculated many strains of cauliflower without finding any that were resistant.

Similar work was carried on with brussels sprouts and in this case one strain was found that showed distinct resistance (Plate VI). Selections have been made from this strain and seed grown. These were tested in the field in 1926 and some of them showed promise. The work will be continued, tho there is doubt whether a black-leg resistant strain would be used by the growers since they are successfully controlling the disease by the rotation-seed treatment program and prefer to use special strains of seed that they have found suited to their needs and which they consequently value highly. The writer is of the opinion that in general the use of disease resistant varieties will be undertaken by the growers only as a last resort when other control measures fail.

What can be done after the disease once appears in the field? This is a question that growers often ask, and generally the answer is, nothing. However, if the disease is observed soon after the plants are set and the grower is satisfied that his loss is going to be severe, he can follow the example of one man who went to work and replanted 6 acres, using healthy plants purchased from another grower and setting the new plants in the intervals between the diseased ones. This field when examined in the fall showed the second setting of plants healthy and producing a good crop, while the original setting of plants were for the most part dead and dried up. Many growers have lacked the courage to replant entirely in this manner and instead they have attempted to replant as the original plants died out, setting a new plant in place of the dead one. This procedure has met with little success, chiefly because the plants die a few at a time, starting early and continuing thruout the season.

HOW TO USE THE HOT WATER TREATMENT

The hot water treatment recommended consists *first* of a germination test by which weak lots of seed are detected and discarded, and *second* of the actual heat processing. The heat processing recommended comprises 25 minutes at 122° F for cabbage and brussels sprouts to destroy both black-leg and black-rot infection. Cauliflower seed does not carry black-leg and 18 minutes at the same temperature is effective against black-rot (blight), consequently this shorter treatment is to be used for cauliflower seed.

THE CENTRAL TREATING STATION

The practical method of using the hot water treatment is at a central heating station. Generally speaking, individual growers have neither the experience nor the facilities to do the work properly and they should either bring their cabbage, cauliflower, and sprouts seed to such a station for test and treatment or else purchase seed already treated.

Furthermore, it is recommended that seed dealers who wish to sell treated seed should also have this seed tested and treated at the central station. The average dealer is in little if any better position than the grower to test and treat seed properly, and growers certainly would have little confidence in the work they did.

The county agent is usually the person best qualified to operate the central treating station. He is financially interested in neither dealer nor grower and hence can do the work of testing and treating with the full confidence of both. He is technically trained and has the support of the experts of the Extension Service and Experiment Station staff. Therefore, in localities where the demand is sufficient, the establishment of a central testing and treating station under the supervision of the county agent is recommended.

To test out the practicability of a central testing station on Long Island, in 1925 the writer established such a station on the Vegetable Research Farm and operated it for three years. The service was strongly supported by the growers and equally so by the dealers. The plan of operation developed at this station was as follows.

Growers or dealers having seed they wished treated sent in a sample as early in the winter as possible. This sample was tested and if the results of the tests were satisfactory the owner of the seed was later notified when to bring the seed to the treating station. It was found desirable to secure samples during December and

January and to use this latter month for testing and then to start treating about the first of February. The treating station was operated on alternate Tuesdays until the middle of April. At the station the seed was treated and dumped out (large lots) or hung up (small lots) to drain, after which it was taken away by the owner to dry. Samples received for preliminary tests were preserved and also additional ones taken from the main seed lot before and after treatment.

The operation of a treating station has required much careful attention to details, but the seed is not bulky and hence the actual treating was not a laborious task. The writer processed about 1,200 pounds of sprouts and cauliflower seed a season the second and third years he operated. At the rate of 4 ounces per acre this quantity is sufficient to plant 4,800 acres. The value of this seed was not less than $24,000, while the value of the crop produced ranged from practically nothing to over $1,000 per acre. Considering that seed treatment may make the difference between crop failure and crop success the money involved is certainly enough to justify the most careful and accurate work.

SAMPLING AND TESTING THE SEED

Count two 500-seed samples, and treat and dry one sample. Sow both side by side in a flat of soil in the greenhouse. The soil used should be sterilized by steaming one hour, otherwise, especially in midwinter, damping-off fungi may spoil the test. A convenient soil sterilizer can be made by constructing a box of wood or concrete with perforated steam pipes at the bottom. A grating of slats covered with a loose piece of burlap is laid on top of the steam pipes and the soil on top of this. Flats 12 x 18 x 2 inches are a convenient size, and each flat will take two samples sown in four rows. For accurate work, seed must be sown at a uniform depth. This is accomplished by first filling the flats, packing and leveling the soil with a stick. Rows of uniform depth are then made with a 12-inch piece of lath notched at either end so as to make a furrow half an inch deep when pressed down into the soil. The edge of the lath should be smoothed and sharpened.

READING THE TEST

The germination counts are ready to read when the plants are an inch high which will be from 12 to 14 days after sowing the seed. In making the counts, all plants half an inch high or more are in-

cluded, but no attention is paid to weak individuals which may be just above ground. The object of this germination test is not to secure a fine, high figure to print on the outside of the envelope but to measure the strength of the seed. Under the conditions outlined, good lots of cauliflower seed will test from 60 to 75 per cent and good lots of sprouts and cabbage from 75 to 90 per cent. The figures secured in this test, however, are from 10 to 20 per cent higher than the same seed will give when sown in the field under good conditions.

Lots of seed that test below 60 per cent are liable to give a poor stand when sown in the field, while lots testing below 50 per cent are almost certain to cause trouble. Consequently, it is desirable not to treat seed germinating below 60 per cent, tho with favorable conditions it may give a satisfactory come-up. Furthermore, weak seed does not stand treatment as well as strong. The soil germination test alone will give reliable results with seeds of these crops. Tests on blotters or by similar methods yield results that are very difficult to interpret in terms of field conditions. To give an extreme example, a certain dealer sent seed to a local seed house for test and they reported between 70 and 80 per cent germination. The author planted it in soil in the greenhouse and secured 15 plants from 500 seeds, and also sowed it out of doors where it failed completely to come up. This seed had sufficient strength to crack the seed coat, but not sufficient to enable it to push up thru soil.

In all cases where there is doubt as to whether a seed stock is strong enough to be accepted for treatment, the best procedure is to hold the treated and untreated samples a month and then retest. If the seed is weak, the treated seed will by that time germinate poorer than the untreated. This delay is possible if the samples are secured early in the winter, and every effort should be made to do this.

TREATING THE SEED

Seed may be treated on a large scale, using barrels to hold the water, wire-mesh baskets to hold the seed, and steam for heat (Plate VIII); or on a small scale, using buckets or tubs, bags, and hot water. To allow for swelling, the containers, whether bags or baskets, should not be filled more than half full. If bags are used, it is important to twist the loose portion tightly and expel as much air as possible, then drop them into the water and untwist. If this is not done a large amount of air is held in very tightly and the bags may float.

When adding steam or hot water to maintain the temperature, it is not necessary or desirable to remove the seed since this again will fill the wet bags with air. Instead, stir thoroly, either by moving the seed container up and down several times or else with a paddle. After the treatment is completed large lots of seed should be spread out at once so that the heat may help dry them. Seed dumped out in this way and stirred at intervals will show no free moisture after a couple of hours.

DRYING THE SEED

A reasonable amount of attention is necessary to dry the seed properly. The best procedure is to use racks and trays which will permit circulation of air below as well as above the seed. A good sort of tray is made by covering a light wooden frame with chicken wire and laying cheesecloth or other light-weight material on top. If it is necessary to spread on boards, a layer of paper first will hasten the drying. For the first couple of days it is essential that the seed be stirred several times daily. Complete drying will require from 5 to 14 days, depending entirely on conditions, and the more rapid the drying the better. Seed will mold if drying conditions are not satisfactory. Seed lots will usually weigh from 3 to 8 per cent less after being treated and dried than they did before treatment. Part of the loss is dirt and part soluble material from the seed coat.

EFFECT OF HOT WATER TREATMENT ON GERMINATION

The hot water treatment carried out under the above conditions has been used on a large scale for three years. During this period

TABLE 5.—GERMINATION TESTS WITH BRUSSELS SPROUTS IN FIELD, 1927.

SEED STOCK	UNTREATED SEED		TREATED SEED (25 minutes at 122°F)		PERCENTAGE DECREASE RESULTING FROM TREATMENT
	Number of plants	Percentage germination	Number of plants	Percentage germination	
J. F. Douglass	314	62.8	297	59.4	3.4
H. S. Duvall	298	59.6	331	66.2	6.6 (In-
J. F. Young	277	55.4	224	44.8	10.6 crease)
W. Haberman	369	73.8	305	61.0	12.8
George Hallock	329	65.8	286	57.2	8.6
Peter Hand					
Lot No. 1	359	71.8	263	52.6	19.2
No. 2	233	46.6	199	39.8	6.8
No. 3	314	62.8	215	43.0	19.8
No. 4	279	55.8	231	46.2	9.6
Average					9.4

literally thousands of germination tests in greenhouse and field have been made and scores of seedbeds examined. It would not be worth while or possible to present all figures. The results of some field tests, made in 1927, however, are a good sample and will show what reduction in stand may be expected from the seed treatments here recommended. (See Tables 5 and 6.)

TABLE 6.—GERMINATION TESTS WITH CAULIFLOWER IN FIELD, 1927.

SEED STOCK	UNTREATED SEED		TREATED SEED (18 minutes at 122°F)		PERCENTAGE DECREASE FROM TREATMENT
	Number of plants	Percentage germination	Number of plants	Percentage germination	
Association Snowball					
Lot No. 1	210	42.0	220	44.0	2.0 (Increase)
No. 2	262	52.4	210	42.0	10.4
No. 3	284	56.8	285	57.0	—
Association Erfurt					
Lot No. 1	259	51.8	240	48.0	3.8
No. 2	275	55.0	305	61.0	6.0 (Increase)
No. 3	235	47.0	260	52.0	5.0 (Increase)
No. 4	281	56.2	281	56.2	—
Millers Erfurt					
Lot No. 1	214	42.8	280	56.0	13.2 (Increase)
No. 2	264	52.8	253	50.6	2.2
Millers Snowball	290	58.0	278	55.6	2.4
Association H. S. Erfurt	286	57.2	229	45.8	11.4
Berlin Forcing	287	57.4	254	50.8	6.6
Meyjes Erfurt	283	56.6	239	47.8	8.8
Average					1.5

From the above figures it is apparent that the more severe treatment used on sprouts reduced the germination perceptibly, while the milder cauliflower treatment had little effect.

HOW TO SOW SEED

A discussion of how to sow seed might seem out of place here but for the fact that five years' field experience has shown that many farmers do not know how to sow seed and often blame the seed for poor stands that are the result of their own ignorance or carelessness.

Long Island growers sow seed in field beds and the first essential in the preparation of a good seedbed is that it be made well in ad-

vance of the date of sowing. The land should be plowed, harrowed, fertilized, and smoothed so that it is all ready for seeding, and then it must be allowed to lie at least two weeks for rains to settle and pack. After the bed is properly settled all the preparation that is necessary before sowing is to scratch the surface with a rake or weeder to give a scant inch of loose soil. Many make the mistake of using a harrow and stirring the soil thoroly to a depth of 3 inches with the resul tthat this loose soil soon dries leaving the freshly sown seed without moisture. Further, where there is so much loose soil the drill sinks in and plants the seed too deep. With a thoroly prepared bed, however, the seed is sown about three-fourths inch deep and lies on soil which is moist and undisturbed. Seed sown in this way will germinate and come up during dry weather because the solid bed on which the seed lies is moist. In addition, the seed is sown shallow enough so that a rain will not wash it out, nor is it so deep as to have difficulty getting above ground. Many growers cover cauliflower seed with drift sand to prevent caking, and this is a good practice but not essential if the bed is properly made.

Cauliflower seed should be planted at the rate of 1 ounce per 120 to 150 feet of row—depending on the strength of the seed. Sprouts and cabbage seed should be sown at the rate of 1 once per 150 to 200 feet of row, also depending on the strength of the seed. It is an interesting fact that weak lots of seed may, when sown too thin and too deep, give practically no stand because the seedlings are unable to force their way thru the surface soil crust, while strong lots of seed will give fair stands even under unfavorable conditions. Cauliflower seed stocks tend to be weak and require careful attention to planting details for satisfactory results.

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